

Clim. Past Discuss., referee comment RC2
<https://doi.org/10.5194/cp-2021-154-RC2>, 2022
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Comment on cp-2021-154

Ignacio Jara (Referee)

Referee comment on "Palaeobiological evidence for Southern Hemisphere Younger Dryas and volcanogenic cold periods" by Richard N. Holdaway, *Clim. Past Discuss.*,
<https://doi.org/10.5194/cp-2021-154-RC2>, 2022

Overview

The author presents a series of radiocarbon chronologies of fossil moa remains covering the Last Glacial Maximum (LGM) and the Last Termination (LT) from several fossil sites in the South Island of New Zealand. The climate interpretation of the ^{14}C sequences assumes that moa species are in strict association with specific vegetation types; and uses New Zealand's $\delta^{18}\text{O}$ speleothem series as a master temperature record. The moa chronologies are then evaluated in the light of long-lasting debate about temperature changes during lateglacial times in New Zealand, coming up with a rather controversial claim of rapid warming during the Antarctic Cold Reversal (ACR; 14.6-13 kcal BP) and significant cooling aligned with the Younger Dryas chronozone (YD; 12.9-11.7 kcal BP).

Although the use of habitat-specialist moa species as a proxy for temperature change is definitely a novel approach, and even though the author have made a comprehensive revision of the published radiocarbon chronologies; the manuscript does not seem to provide the sufficient evidence and the necessary revision of the vast literature to sustain some of its main conclusions.

For instance, the author argues than moa fossil assemblages are a more direct climate proxy than pollen or isotopes records, yet this hard to justify considering that the moa's habitat specificity could have certainly changed in the face of rapid landscape changes, and that the chronologies presented in the manuscript represent a discontinuous record of individual, ephemeral paleoecological events.

The results presented by the author challenge the present model of inter-hemispheric relationship between climate events during the LT, and therefore hold large implications for the Quaternary paleoclimate community. To sustain such a big claim, a convincing explanation about why significant warming (cooling) occurred in NZ during the ACR (YD) at the same time than several other mid-latitude terrestrial records were documenting significant cooling (warming) is essential. Unfortunately, it is missing in the text.

Specific comments

Lack of a hemispheric perspective

The results presented in the manuscript challenge the current consensus about the climate events that characterised LT in the Southern Hemisphere. In this regard, the author fails to place the NZ moa chronology within a continental paleoclimatic context. There is solid evidence, from a good number of high resolution, well-dated climate records, to sustain an extension of the Antarctic deglaciation pattern into the Southern Hemisphere mid-latitudes; however, only a very small number of studies are mentioned or discussed in the main text.

I suggest the inclusion and thorough revision of the some of the most recent literature concerning this topic, included but not limited to:

- Fletcher, M.S., Pedro, J., Hall, T., Mariani, M., Alexander, J.A., Beck, K., Blaauw, M., Hodgson, D.A., Heijnis, H., Gadd, P.S. and Lise-Pronovost, A., 2021. Northward shift of the southern westerlies during the Antarctic Cold Reversal. *Quaternary Science Reviews*, 271, p.107189.
- Mendelova, M., Hein, A.S., Rodes, A., Smedley, R.K. and Xu, S., 2020. Glacier expansion in central Patagonia during the Antarctic Cold Reversal followed by retreat and stabilisation during the Younger Dryas. *Quaternary Science Reviews*, 227, p.106047.
- Sagredo, E.A., Kaplan, M.R., Araya, P.S., Lowell, T.V., Aravena, J.C., Moreno, P.I., Kelly, M.A. and Schaefer, J.M., 2018. Trans-pacific glacial response to the Antarctic Cold Reversal in the southern mid-latitudes. *Quaternary Science Reviews*, 188, pp.160-166.
- Hinojosa, J.L., Moy, C.M., Vandergoes, M., Feakins, S.J. and Sessions, A.L., 2019. Hydrologic change in New Zealand during the last deglaciation linked to reorganization of the Southern Hemisphere westerly winds. *Paleoceanography and Paleoclimatology*, 34(12), pp.2158-2170.
- Moreno, P.I., Denton, G.H., Moreno, H., Lowell, T.V., Putnam, A.E. and Kaplan, M.R., 2015. Radiocarbon chronology of the last glacial maximum and its termination in northwestern Patagonia. *Quaternary Science Reviews*, 122, pp.233-249.

As the evidence presented in this manuscript is not discussed in the light of these (and

several others) studies, the author omits an explanation for why the Moa chronologies suggest a warming-cooling pattern during the ACR-YD intervals, whilst terrestrial records from other southern mid-latitudes regions indicates the opposite climate pattern.

In addition, no Antarctic ice core data has been included in the figures or discussed in the main text. It is rather surprising that the manuscript places so much attention to the Greenland ice core data without mentioning or discussing the detailed Antarctic ice core isotope or gas timeseries. It seems that the author is over-stressing the data that agrees with its interpretation of the moa sequences (i.e., NZ speleothems, Greenland ice cores), to the detriment of a great number of detailed and well-dated records from NZ, the mid-latitudes, and Antarctica.

Radiocarbon sequence of moa as a proxy for hemispheric climate events

The author indicates that -unlike pollen, cosmogenic chronologies, or speleothems- the radiocarbon record of fossil moa remains provides an unbiased and precise indication of climate variability during the LGM and the LT. In my opinion this assumption may be flawed, as the link between the presence/absence of moa species and climate conditions is in fact quite indirect.

For instance, why moa remains are a better indicator of past vegetation than pollen assemblages?

Animals may change their diet specificity in response to climate alterations, and this could have certainly been the case for the moa species during the abrupt environmental changes while the world was thawing from the last glaciation. Hence, the changes in moa species during this time may be as an indirect climate proxy as pollen, isotopes, or other paleoclimate indicators.

Resolution of the moa radiocarbon sequences

While the author has made a great effort compiling a significant number of radiocarbon ages from moa fossil sites, some of the most critical inferences are based only on a small number of samples. For instance, the appearance of *Pachyornis australis* in the Takaka Hill site during the YD (indicative of cold/dry climates) is sustained just by two samples. Similarly, the responses to the Oruanui and Mt Takahe volcanic eruptions are inferred from a very limited number of radiocarbon dates.

Interpretation of the data

The current understanding derived from the literature is that the ACR was expressed in the Southern Hemisphere mid-latitudes either as a cooling interval or as a period with a slower warming rate. Furthermore, a significant increment in precipitation has been documented in west-facing continental areas as a result of an equatorial shift of the Southern Westerly Winds (SWW).

Such a SWW migration did more likely increase precipitation levels over most of western and southwestern New Zealand. Under this scenario:

*Could the replacement of *P. australis* (cold/dry forest) by *Anomalopteryx didiformis* (warm/moist lowland forest) during the ACR have partially resulted from raising moisture levels rather than being a strictly warming signal?*

*Similarly, may the reappearance of *P. australis* during the YD chronozone respond to a sustained drying as the SWW shifted southward at the end of the ACR?*

On the other hand, it is worth to note that the driver of the speleothem isotopic records has long been debated, with no current consensus that they wave a purely temperature signal. The author assumes that they represent genuine temperature records based on the similarities with the Greenland ice core isotope series. The author should discuss the potential driver and limitation of the NZ speleothem records, for which I suggest the following literature:

- Newnham, R.M., Vandergoes, M.J., Sikes, E., Carter, L., Wilmshurst, J.M., Lowe, D.J., McGlone, M.S. and Sandiford, A., 2012. Does the bipolar seesaw extend to the terrestrial southern mid-latitudes?. *Quaternary Science Reviews*, 36, pp.214-222.
- Barrell, D.J., Almond, P.C., Vandergoes, M.J., Lowe, D.J., Newnham, R.M. and INTIMATE members, 2013. A composite pollen-based stratotype for inter-regional evaluation of climatic events in New Zealand over the past 30,000 years (NZ-INTIMATE project). *Quaternary Science Reviews*, 74, pp.4-20.

Moa key morphological features

Although the systematics adopted by the author is explained in section 2.2, there is no discussion on which morphological features distinguish the different moa taxa discussed in the manuscript. This is an important element since the climate interpretation of the radiocarbon chronologies is based on the identification of different moa species. A brief discussion on the potential problems or limitations in the moa fossil identification would be desirable.

Excessive number of smoothed curves

Figure 2, 3, 4, 10 and 11 present all several different smoothing factors for the same dataset. Although the author has done a valuable effort to obtain the most representative long-frequency signal from the raw isotopic data, the great number of curves derived from the same original series makes the diagram hard to understand and, in many cases, respective. I would suggest choosing one smoothing factor, provide a justification for its selection, and use that single one for all the following figures. A diagram with all the different smoothing factors could be added in the supplementary information

Minor changes

Lines 31-32: Please provide age interval for the ACR.

Line 55-56: why Antarctic Ice core records were omitted?

Line 68: It is not necessary to include the annual sunshine hours.

Line 69: A reference is needed for "...the Holocene vegetation has been lowland rainforest...".

Line 112-113: A reference is needed for "The Holocene TV rain forest was much floristically richer than that on TH.".

Line 126: Merino Cave is not seen in Figure 1.

Line 210-214: All the different smoothing factors tested should be added in the supplementary information. For sake of simplicity and for a more straightforward reading of the text, only a single smoothed curve should be used in the figures.

Line 212-213: "At all SF values, the fall in temperature..." This statement is actually a result and should be moved to section 3.

Line 212-213: The fact that the cooling observed in all smoothing curves coincide with the

YD as defined in Greenland records is just partially true. In William et al 2010, the lateglacial cooling is observed between 13.4-11.2 kcal BP, so that it starts ~500 years earlier than the Northern Hemisphere YD.

Line 311: consider change "just preceding" by "prior to".

Line 385-387: I challenge this statement. Moa chronologies are as indirect climate proxies as isotope or pollen timeseries. They do not record a direct temperature change, but rather changes in the moa habitat preferences, driven by vegetation change, which in turn respond to climate change.

Line 414: consider removing "both".

Line 424: Please correct "Instead, therefore,".

Figures and Tables

Figure 1: "Fossil deposits, black; speleothem sites, white". I think it is actually the opposite. Please revise.

The site "A" Mt. Arthur (Nettlebed Cave) is not seen in the maps.

Figure 2: The author should consider simplifying this image with only a single selected smoothed factor on it. As all the different smoothing factors show the same pattern, the selection between them is not directly relevant for the topics discussed in the manuscript. Hence, the entire set of smoothing curves could be moved to the supplementary information.

Figure 5: A label for the YD interval (represented by a long vertical bar) is missing. A similar geometrical indicator for the ACR would be desirable.

Figure 8: Insert B seems not be necessary because the changes in the extent of the Cook Strait during the last termination are not discussed in the main text, nor the focus of the core discussion of the data.

Figure 9: Line 360- please indicate what $\delta^{18}\text{O}$ record is used in Figure 9c.

Figure 11: This figure is basically the same as figure 9d, and therefore its presence on the main text is not strictly necessary.

Table 1: Why only the bold date was used for the sequence analysis?

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